A MICROFAUNAL STUDY OF THE BASAL LLOYDMINSTER SHALE

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A MICROFAUNAL STUDY OF THE BASAL LLOYDMINSTER SHALE

A DISSERTATION

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

FACULTY OF ARTS AND SCIENCE

by

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EDMONTON, ALBERTA,

APRIL, 1950.

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ABSTRACT

Statistical analyses of microfauna from the Lower Cretaceous, lower Lloydminster shales from the Eldorena #1 well of the Edmonton area, Alberta, indicates continuous deposition without important stratigraphic interruptions throughout, superjacent to, and subjacent to the Viking sand member.

An Ammobaculoides microfauna, older than any previously described from the Lloydminster shale, is reported from the base of the formation.

Parts of the lower Lloydminster shale are correlated with the upper 200 feet of the Buckinghorse formation of north-eastern B.C.; the lower 80 feet of the Shaftesbury formation of Peace River area, Alberta; the Joli Fou - Pelican sandstone basal Labiche shale of the Athabaska River area, Alberta; and with the lower Lloydminster shale of the Vermilion area, Alberta.

Statistical data is presented in convenient histogram charts.

CHAPTER I

INTRODUCTION

Introductory Statement

This thesis is an analytical microfaunal inventory of the basal Lloydminster shale. The analysis was selected to embrace the Viking sand member of the Lloydminster shale.

The results of this study indicated that no distinct or abrupt faunal change occurred during the deposition of the Viking sand, immediately preceding it or immediately following, within the Eldorena area and therefore the Viking sand represents sandy facies of the early Lloydminster flooding and in this area does not indicate a stratigraphic hiatus.

Collection & Preparation of Samples

The samples, from which the microfauna were obtained, were collected by Mr. C.R. Stelck from drilled cores of Eldorena #1 Well, taken by Imperial Oil Ltd. in 1949.

The samples were collected continuously and irregularly, along the cores, the footage being determined by convenient length interval where no lithological change was involved, and by selective picking of shale intervals where sandy breaks provided lithological markers. This method permits an unmixed evaluation of fauna from individual shale tongues. The samples range from 1934 feet to 2128 feet (drilling depth), i.e. from the top of the Mannville formation to about 50 feet above the Viking sandstone.

The samples were placed in postal cotton bags and forwarded to the University of Alberta.

The writer divided the samples into two parts, breaking the fragments by hand to minimize the amount of crushing and consequent damage to any microfossils contained. One half of each sample is placed in a pint sealer for immediate use, and the remaining half retained in the sample bag and is filed in the Department of Geology of the University of Alberta. Each pint sealer is filled approximately three fourths full with ordinary tap water and sealed.

When the samples have softened sufficiently they are shaken vigorously to allow as much of the shale as possible, to become suspended in the water. The contents of the sealer are emptied into a prepared set of Tyler screens. These screens consist of the following suite: 28 mesh, 48 mesh, 80 mesh, 100 mesh, 150 mesh and a pan. A small stream of water from a rubber tube connected to the water tap reduces the residue on the 28 mesh screen. The residue is worked with the fingers and the remaining residue is collected to one side of the screen by means of a fine jet of water from the underside of the 28 mesh screen, and washed into a white porcelain saucer. The excess water is then poured out of the saucer and the residue allowed to dry.

This procedure is carried out with each screen size. A small stream of water is allowed to run into the pan and float off all shaly particles, leaving the microfossils and sand grains, etc. behind. This sample is also transferred to a porcelain saucer.

When the sample is dried, each mesh size is placed in a small screw-topped vial and appropriately labelled.

Method of Mounting Microfossils

The residues in the screw-topped vials contain the microfossils. The residue is scattered thinly over the surface of a "picking" plate - a small buff-colored plastic plate. The picking is done under a Bausch and Lomb binocular microscope at 30X magnification, using a blue light. The picking plate has a sectioned field, and the percentage of the sample picked is readily determined.

The microfossils are picked up on the tip of a moistened paint brush (00). The fossils are placed, and roughly grouped as to genus, on a clean, white card. Where sufficient numbers of fossils have been collected and the percentage of the sample is determined, the residue is returned to the vial. The fossils are then transferred to a mounting slide. Some of these slides contain one large rectangular cell in which case the different mesh sizes of each

sample are marked off along the sides of the cell; other slides contain 10 small, circular cells arranged in two rows of 5 cells, along the length of the slide, in which case each mesh size is confined to one cell and each sample to a row of 5 cells (i.e. - two samples of 5 cells each, per slide).

The cells of the mounting slides, have a black background which is covered with gum tragacanth, which, when touched by the moistened brush holding the fossil, becomes gummy and holds the fossil securely. The fossils are arranged in horizontal rows within the cells.

The slides of the collection, are filed in the Department of Geology, University of Alberta.

Scope of Thesis and Method of Treatment

This dissertation is a statistical evaluation of the microfauna of the Basal Lloydminster shale as represented in cores from the Imperial Eldorena well (LSD 4, Section 27, Township 57, Range 20, West of 4th Meridian). Specifically, it is an attempt by the

writer to analyze the fauna above, below and within the Viking sand with respect to continuity of fauna across the sand.

The method employed was to make statistical counts, both generic and specific, of the faunas. These counts were then studied by the use of check lists and histogram representation, to arrive at the conclusion stated.

Note -- The "species" as set up by the writer were selected as morphologic types and followed through as such, each new morphologic type receiving the specific notation of successive letters of the alphabet.

Acknowledgements

The writer wishes to express his deep appreciation to all members of the Department of Geology, University of Alberta, for their cooperation and encouragement. The writer wishes especially to express his appreciation for the assistance and advice of Mr. C.R. Stelck under whose direct supervision this thesis was written. Mr. Stelck collected the material for the study and suggested the preliminary methods of approach to the problem.

The writer has had access to unpublished works by C.R. Stelck, A.R. Nielsen and W.G. Bahan, on applied phases of this study.

CHAPTER II

STATISTICAL ANALYSIS OF MICROFAUNA

MICROFAUNAL OBSERVATIONS

The following observations on the microfauna of the Lower Lloydminster formation, apply only to the shaly lithofacies and take no cognizance of the faunas that might be present in sandy zones.

The development of the microfauna is best shown by a consideration of each major genus. The discussion of the genera is based on the Generic Occurrence graphs (Figures I - IV), the Percentage Population graph (Figure V), the Specific Occurrence graphs (Figures VI - XII) and the writer's specific evaluation of the fauna.

Haplophragmoides (see Figures I, V and VI) is strongly represented in the lowest shale above the Mannville and is continuously present throughout the section

covered by this thesis. The maximum development both generically and specifically occurs in the shale between the Eldorena sand member (1) and the base of the Viking sand. At this horizon the genus Haplophragmoides represents from 50 to 70 percent of the total population (see Figure V). The minimum development occurs immediately above the shale zone within the Viking sand where only 2 percent of the total fossil population is made up of this genus. The decrease in the percentage representation of Haplophragmoides at this horizon, is taken up mainly by spores.

In species, the same generalizations are true. (see Figure VI) There are 3 species strongly developed in the lowest shale above the Mannville formation and 6 more developed below the Eldorena sand member. Of all 9 species that are present below the Eldorena sand member, only 1 species does not continue

(1) The writer proposes the name Eldorena sand member for the sandy horizon between the Joli Fou (basal Lloydminster) shale and the Basal Member of the Lloydminster shale, (see Figure XIII), at a depth of 2086 feet to 2105 feet in the Eldorena well.

above. There are 13 species present in the shales below the base of the Viking sand -- only 2 of these are represented within the Viking sand and none of them recur above the Viking sand! Of the 3 new species that first develop within the Viking sand only 1 is represented above the Viking and this one only poorly so. (It should be noted at this point that the writer found it impossible to differentiate with certainty, any species contained in the finer screen sizes, viz: 100 and 150 mesh and pan sample). The well known index fossil Haplophragmoides gigas Cushman, occurs in the Basal Lloydminster shale just above the Eldorena sand member and is restricted to that zone.

It may be concluded that with respect to the genus Haplophragmoides, the Viking sand does represent a definite break in specific continuity.

Ammobaculites (see Figures I, V and VII) is represented in the first sample above the Mannville formation. The over all generic development is at no horizon very strong but is consistent throughout the section with the exception of one sample, just above the shale zone

within the Viking sand, where it is absent. There are two maxima of development: one just below the Eldorena sand member of the Basal Lloydminster shale and the other embracing the base of the Viking sand.

Sandy phases do not seem to eliminate Ammobaculites from the section generically or specifically. There are 10 species developed below the Eldorena sand member and 4 of these continue (3 strongly) above the Eldorena sand member (see Figure VII). Of these 4 species, 3 continue for a short way into the base of the Viking and reappear above the Viking sand. One species, not continuous across the Eldorena sand member, reappears above the Viking sand. There are 4 species which have their initial development within the base of the Viking but only 1 of these is represented at all above the Viking. There are 4 species which first develop above the Viking but are only poorly represented within the section considered.

Continuity of Ammobaculites species is interrupted by the sand and sandy phases of the section but some species return with the advent of shale.

Shallow water environment, muddy but marginal to the sandy phases is favored by the genus Ammobaculites. The evidence from the Ammobaculites faunas, shows no hiatus or break present in the section from below the Viking to above the Viking.

Ammobaculoides (see Figures I and V) is a very short ranging genus, strongly represented in the shales up to the base of the Eldorena sand member and thereafter not present. As this genus disappears, the percentage of Haplophragmoides expands to make up the deficit.

The disappearance of the Ammobaculoides implies some important ecological change at the time of the laying down of the Eldorena sand member.

Proteonina (see Figures III, V and VIII) is represented throughout the section except immediately below the base of the Viking. Except for the shale below the Eldorena sand member, there is no great development of this genus. In the percentage population it makes up for decreases in the numbers of Haplophragmoides, Ammobaculites and Ammobaculoides.

The species, generally, are short ranging.

There are 6 strongly developed species represented in the shale below the Eldorena sand member, only one of these survives this sand. However 3 of these species recur very briefly above the Viking. Five species develop within the basal part of the Viking and 4 of these recur above the Viking. The basal suite of species is quite distinctive from the rest of the section.

The evidence from a study of the Proteonina shows no break in section over the Viking interval but some disruption over the Eldorena sand interval.

Reophax (see Figures III, V and IX) is only represented in the Basal Lloydminster by a very few, poor specimens. The first strong development is within the Second Viking sand and all of these are again represented above the Viking sand. Three additional species develop above the Viking sand.

The environment of the Basal Lloydminster shale was not favorable to Reophax suggesting fairly deep water at this time. The evidence of the

Reophax indicates no dissruption in continuous deposition from the Viking to the overlying shales.

Gaudryina (see Figures III, V and X) is strongly developed in the shales of the pre-Eldorena sand member, is fairly strongly represented within the Second Viking sand and again above the Viking sand. Generically it is continuously represented throughout the section.

There are 12 species developed in the shale immediately above the Mannville formation. Gaudryina canadensis and G. cf canadensis are among the 8 of the above species which are confined to this basal horizon. Only 4 of the original and 2 new species appear briefly above the Viking sand. It should be noted here, as in the case of Haplophragmoides, that the writer did not attempt to differentiate specifically those forms found in the finer screen sizes.

Gaudryina are continuous across the Viking sand but evidently the continuity of major species was very badly disrupted by the more sandy environ-

ments. The long range of the Gaudryina species seems to indicate that a fairly short time interval was involved in the deposition of the basal Lloydminster section in this area.

Verneuilina (see Figures III, V and XI), as is to be expected, has a development similar to that of Gaudryina, but is more erratic. The genus Verneuilina is absent at 6 irregularly spaced horizons throughout the section.

There are 2 species present below the Eldorena sand member of the Basal Lloydminster shale, that do not reappear until some 15 feet above the Viking where they occur quite strongly. Two species, one of which is Verneuilina canadensis, develop above the Viking sand.

Generally speaking, the sandy environments have the same affect on the species of Verneuilina as on the species of Gaudryina. The evidence from this corroborates the evidence supporting a short time interval of deposition suggested by the genus Gaudryina.

Miliammina (see Figures I, V and XII) is not present below the Eldorena sand member but first develops in the shale just below the base of the Viking sand. It is quite strongly represented within the Second Viking sand and the shale zone above but is nearly absent throughout the Viking sand proper. It is again strongly represented above the Viking.

The 3 species that develop immediately below the base of the Viking, continue strongly through the Second Viking and return again in the shales above the Viking. The 3 additional species that initially develop within the Second Viking and the shale zone above it are represented above the Viking. There are 2 species which are very poor in numbers, that are initiated above the Viking.

The genus Miliammina is a shallow water form and the generic and specific evidence of the genus in this suite corroborate the previous evidence that the shale above the Viking represents a relatively shallow water environment. There is no disruption of the specific continuity across the Viking interval.

Hyperammina (see Figures I, V and XII) has a distribution very similar to that of Miliammina. It is present, generically, throughout the entire section.

One species develops immediately below the Second Viking and continues through the shale zone above the Second Viking. It reappears above the Viking where there are 7 new species strongly developed, 2 of which had their initial development within the Second Viking and the others in the post-Viking shale.

The evidence of Hyperammina further corroborates that afforded by Miliammina and others. The Viking sand facies was ecologically unfavorable to this genus. There is apparently no disruption of specific continuity through the sand, reaffirming the absence of any important stratigraphic hiatus within the Viking sand section.

Summary

Evidence from the above analyses of the microfauna indicates that there is no major stratigraphic hiatus involved in the Viking sand interval, also that there is no pronounced stratigraphic break immediately above or immediately below the Viking sand. Further, it shows that the time interval involved in the deposition of the Viking sand was not long. The shales below the Eldorena sand represent the initial phase of a transgressive sea which had local embayments of shallow water with deposition during Eldorena sand time. There is nearly continuous deposition through the deep water Haplophragmoides gigas zone.

All genera except the genus Haplophragmoides that are present in the initial shales of the section are represented in the post Viking Shales. Specifically there are faunal ties between pre-Eldorena shales and post-Eldorena shales and between H. gigas zone shales and post-Viking shales indicating that the different faunas represent biofacies changes in the Basal Lloydminster sea and that there is no break in deposition although there are different environments of deposition and varied sediments laid down.

Explanation of Generic Occurrence Graphs

A statistical count is made for genera and graphs compiled (see Figures I - IV). These graphs show the relative development of each genus against the lithology and stratigraphic sequence of the enclosing sediments.

The horizontal component of each graph is a logarithmic progression (i.e. - it is divided into 4 logarithmic divisions, viz: 0 - 10; 10 - 100; 100 - 1000; 1000 - 10,000), the units representing the number of fossils present. The vertical component corresponds to the drilling depth from which the samples were collected.

The writer has chosen to distinguish between count-values under 10 and those over 10 by shading that portion of the graph over 10. This was done to emphasize horizons favorable to the development or preservation of each genus.

Graphs have been drawn up on the following genera: Haplophragmoides, Ammobaculites, Ammobauloides, Reophax, Proteonina, Gaudryina, Verneuilina, Hyperammina, Miliammina, Glomospira, Trochammina, Bothysiphon and Leptodermella. In addition, graphs for the following non-Foraminiferal elements have been drawn up: Spores, Fucoidal Elements and Collophane Spheres.

Explanation of Percentage Population Graphs

The statistical generic count is used to compute the Percentage Population Table (see Table I). This is done by analyzing each sample with respect to the percent of the total population that each individual genus represents. Both Foraminifera and non-Foraminiferal elements are used to give a more complete picture of the Thanatocoenosis of each horizon. The following entities are used: Haplophragmoides, Ammobaculites, Ammobaculoides, Reophax, Hyperammina, Proteonina, Leptodermella, Spores, Gaudryina, Verneuilina, Trochammina, Miliammina and others. The term "Others" includes the following: Collophane Spheres, Bathysiphon, Glomospira, Fucoidal Elements, Tritaxia, Nodosinella, Spiroplectammina, Eoguttulina, Globigerina and Ammodiscus.

The figures are transferred from the table to a graph. The vertical axis of the graph represents the section of the Basal Lloydminster shale dealt with in this thesis and the units represent the drilling

depth at which each sample was collected. The horizontal axis represents the percentage and the units are 10% (viz: 10%, 20% ..... 100%). The percentage of the total population that each genus represents is plotted on the graph. The points are joined by curved lines.

Explanation of Specific Occurrence Graphs

A statistical count is made for each sample, of species populations of each major genus. Graphs are compiled for each genus (see Figures VI - XII). These graphs show the relative development of each species against the lithology and stratigraphic sequence of the enclosing sediments.

The horizontal axis represents the relative numbers of each species present. It is divided into 4 units: a single line representing from 0 to 5 fossils present; a unit bar representing from 6 to 20 fossils present; a 2 unit bar representing from 21 to 100 fossils present; a 3 unit cusp representing from 101 to 1,000 fossils present. The vertical axis corresponds to the drilling depth from which the samples were collected.

In cases where successive samples contain the same species, the continuity is shown by dotted lines. In such cases above the Viking sand where sampling was continuous, the graphic expression is

not broken but is also shown continuously. In samples which are only separated by moderate distances and which contain the same species, the continuity of the species is assumed and indicated by the use of dotted lines.

The following genera are included in the Specific Occurrence Graphs: Haplophragmoides, Ammobaculites, Reophax, Proteonina, Miliammina, Gaudryina, Verneuilina, Hyperammina and Glomospira.

GENERIC OCCURRENCE
of
HAPLOPHRAGMOIDES, AMMOBACULITES, AMMOBACULOIDES and HYPERAMMINA

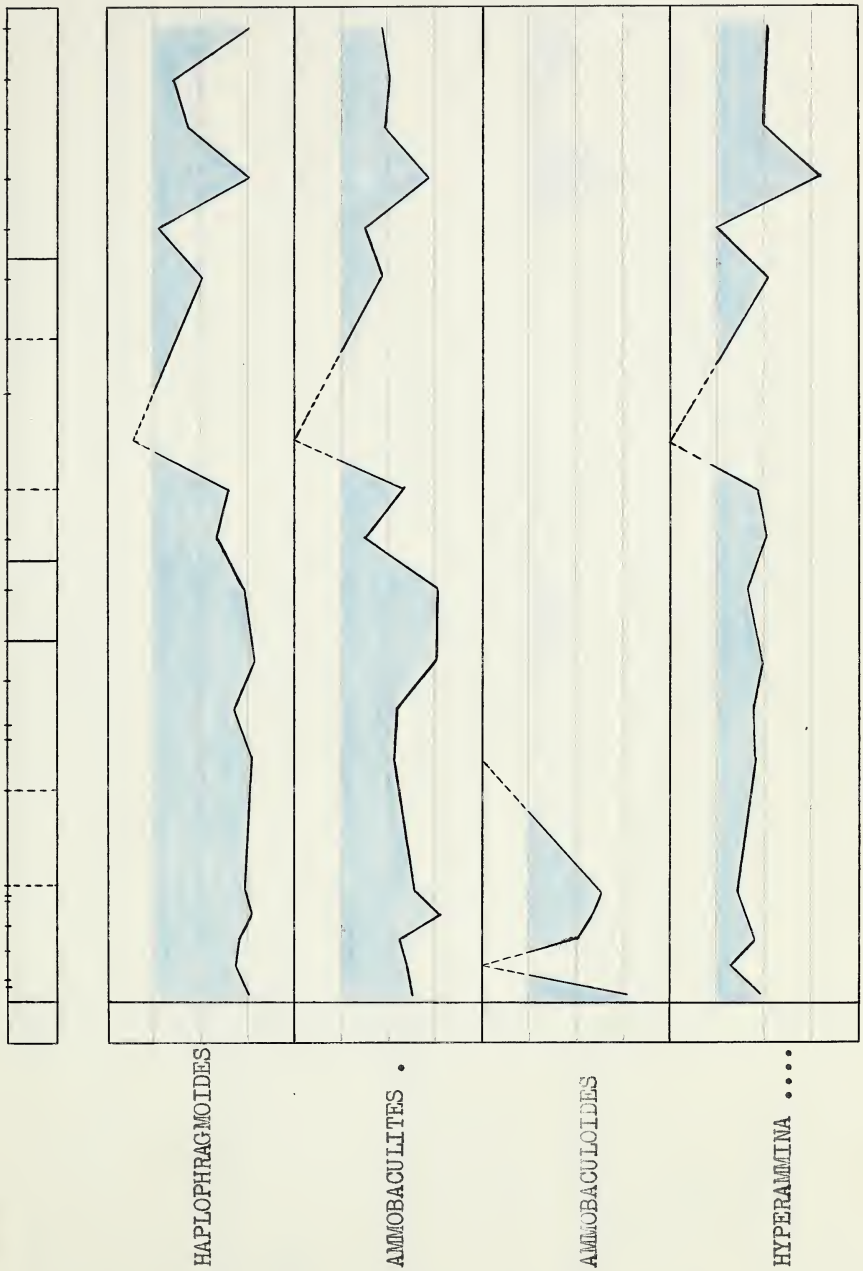

Figure I

GENERIC OCCURRENCE
of
MILIAMMINA, GLOMOSPIRA, TROCHAMMINA and BATHYSIPHON

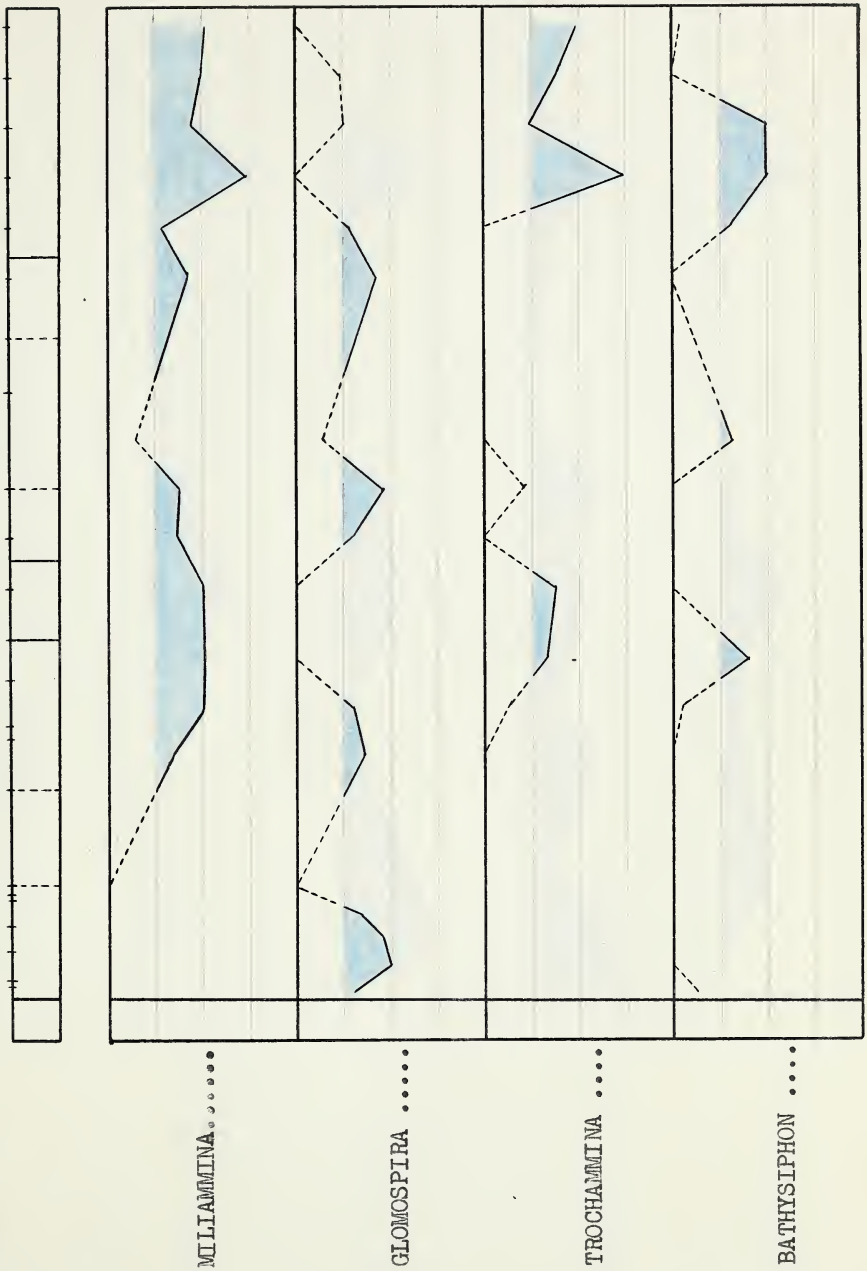

Figure II

GENERIC OCCURRENCE
of
REOPHAX, PROTEONINA, GAUDRYINA and VERNEUILINA

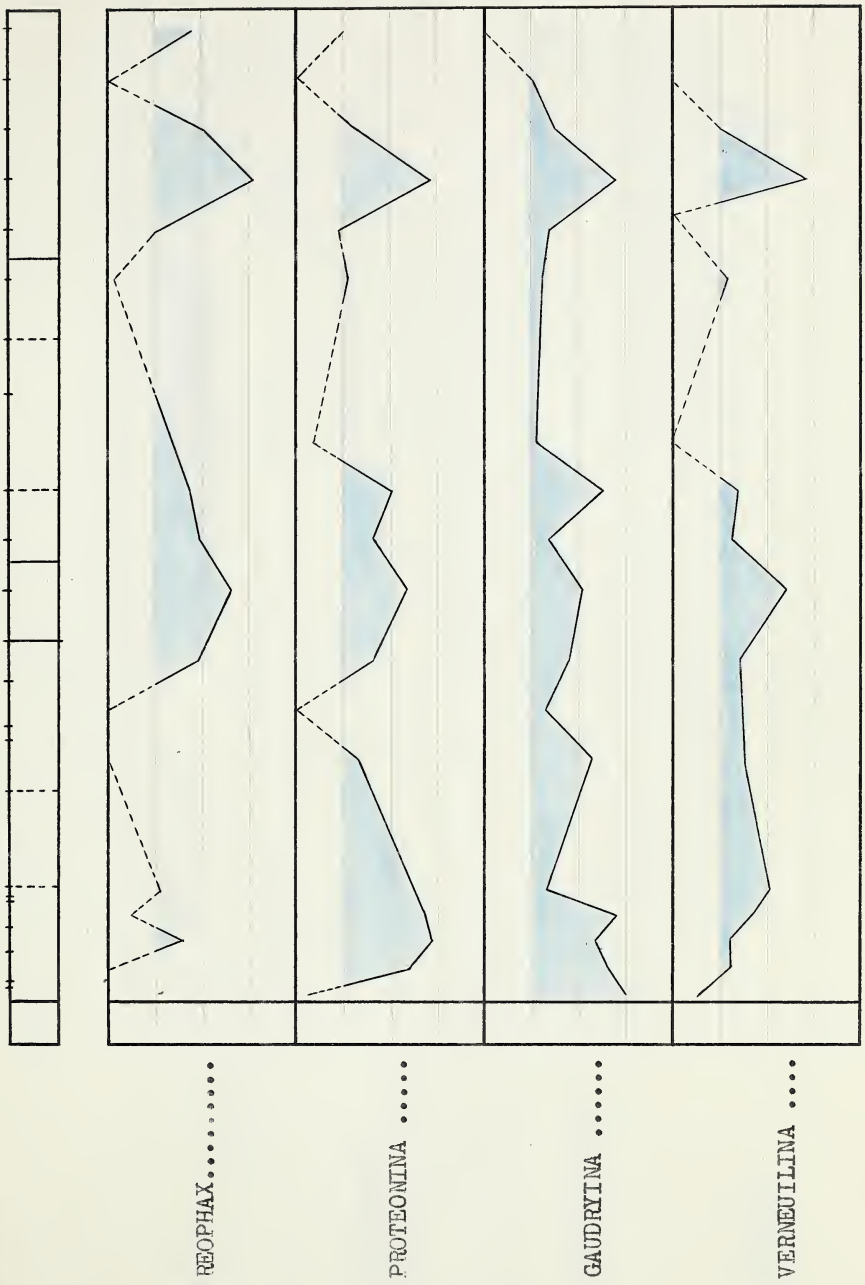

Figure III

"GENERIC" OCCURRENCE
of

SPORES, COLLOPHANE SPHERES, LEPTODERMELLA and FUCOIDAL ELEMENTS

Figure IV

PERCENTAGE POPULATION
of
GENERA

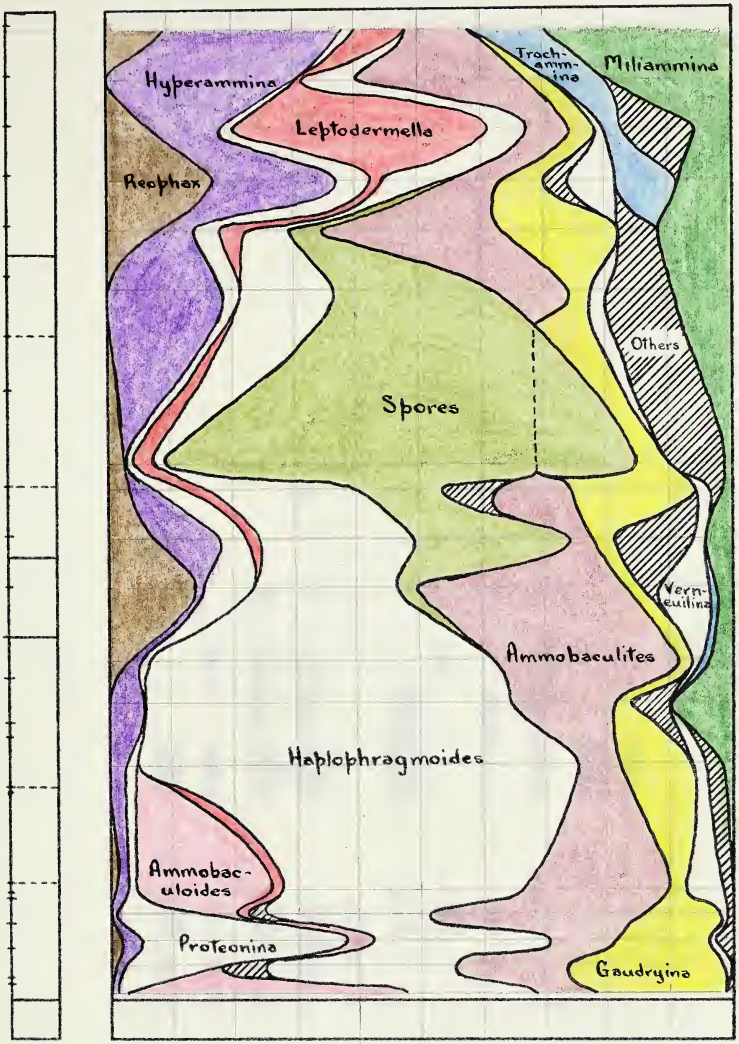

Figure V

SPECIFIC OCCURRENCE
of
HAPLOPHRAGMOIDES

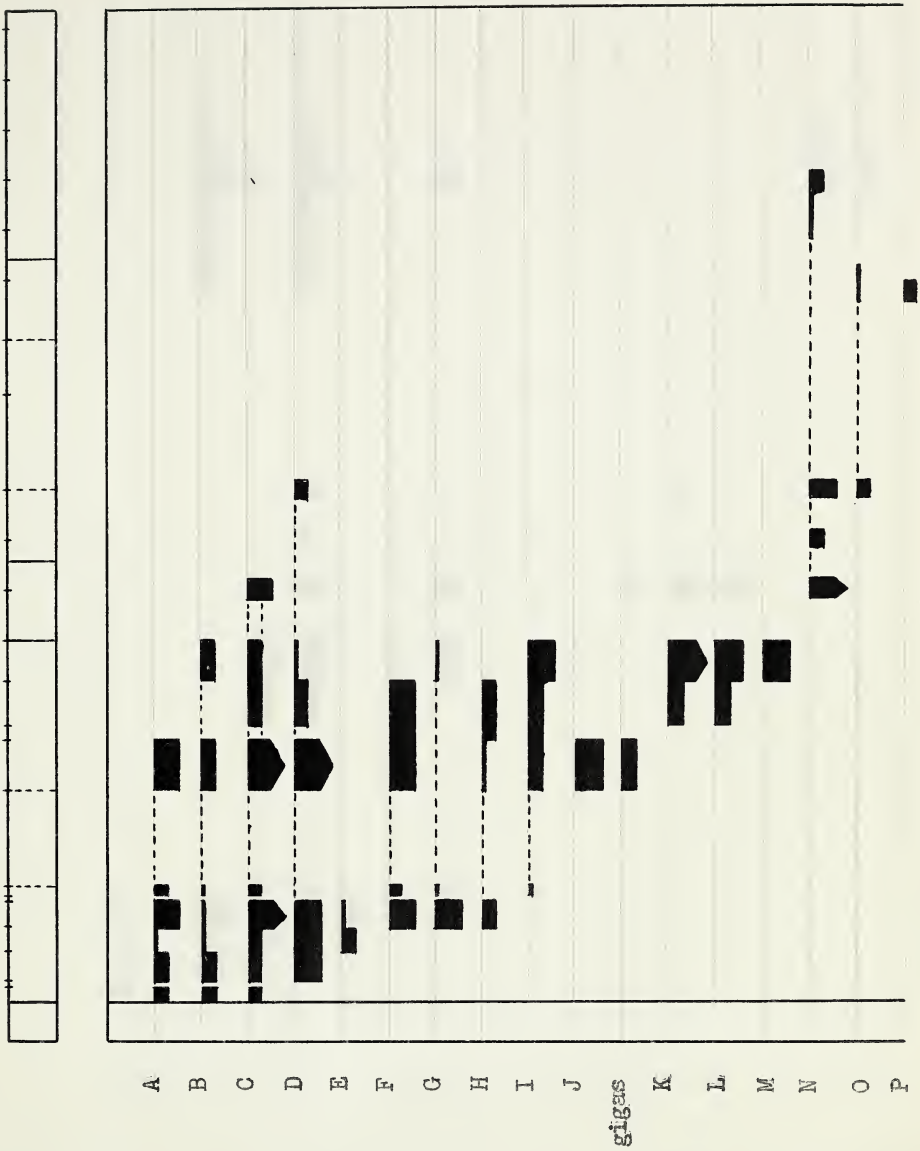

Figure VI

SPECIFIC OCCURRENCE
of the genus
AMMOBACULITES

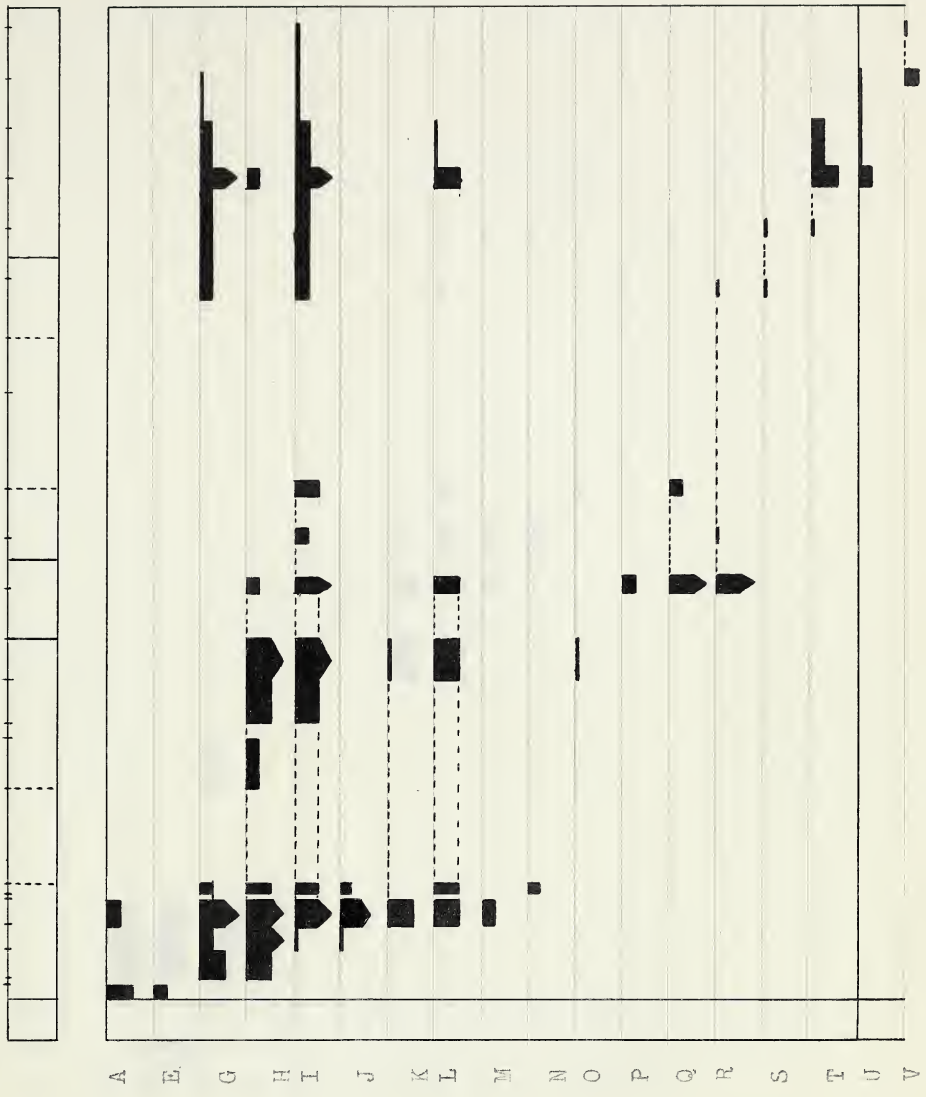

Figure VII

SPECIFIC OCCURRENCE
of
PROTEONINA

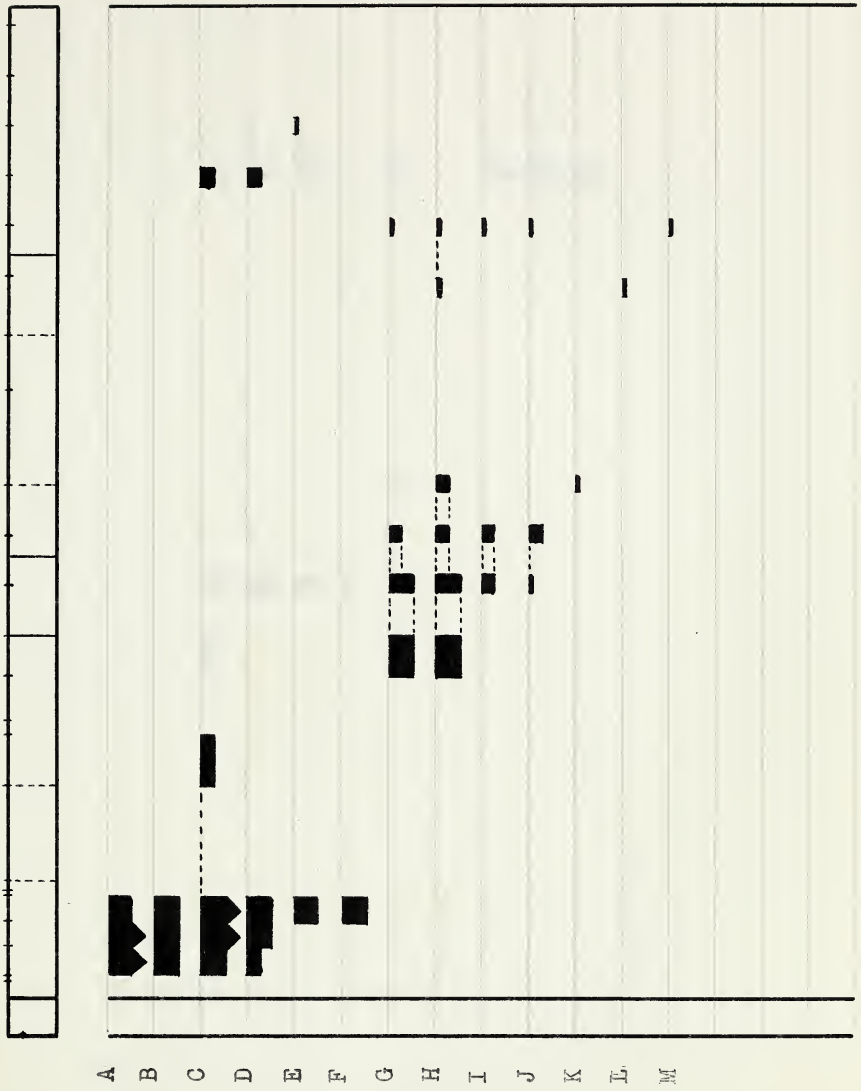

Figure VIII

SPECIFIC OCCURRENCE
of
REOPHAX

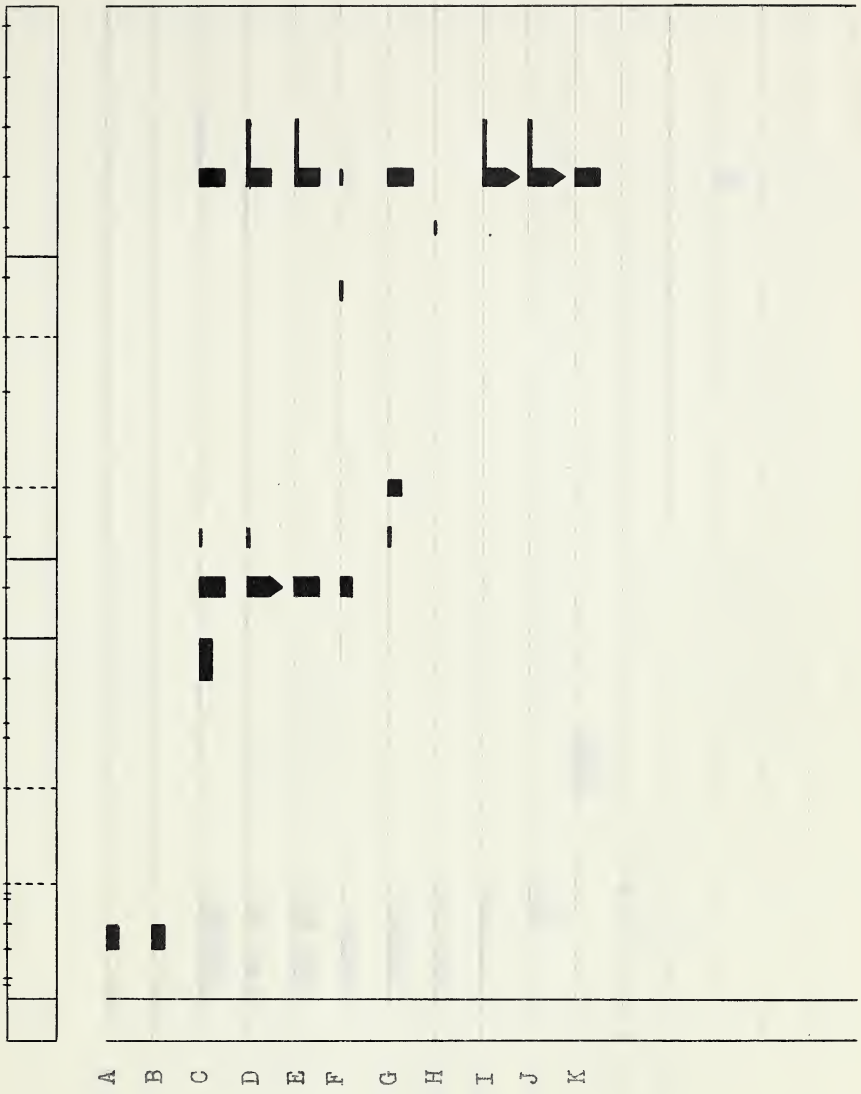

Figure IX

SPECIFIC OCCURRENCE
of
GAUDRYINA

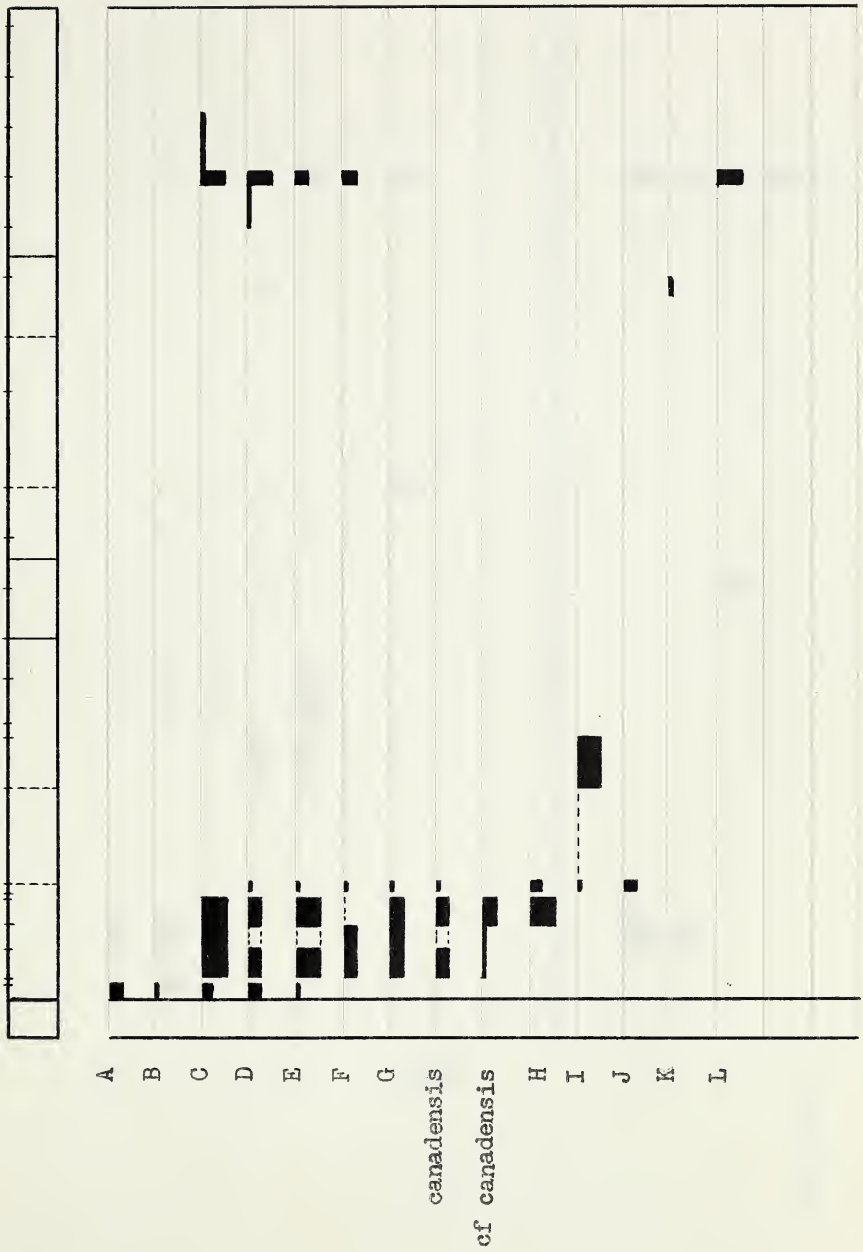

Figure X

SPECIFIC OCCURRENCE
of
GLOMOSPIRA and VERNEUILINA

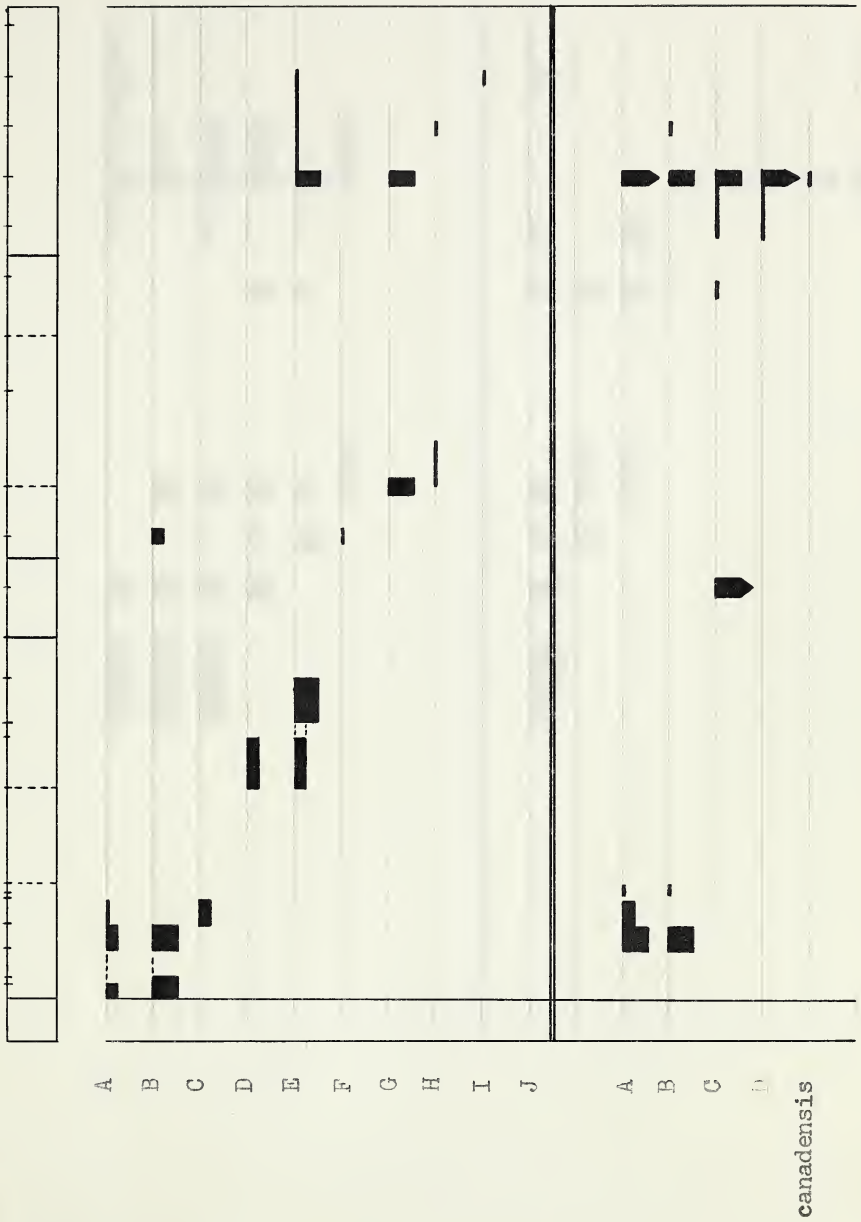

Figure XI

SPECIFIC OCCURRENCE
of
MILIAMMINA and HYPERAMMINA

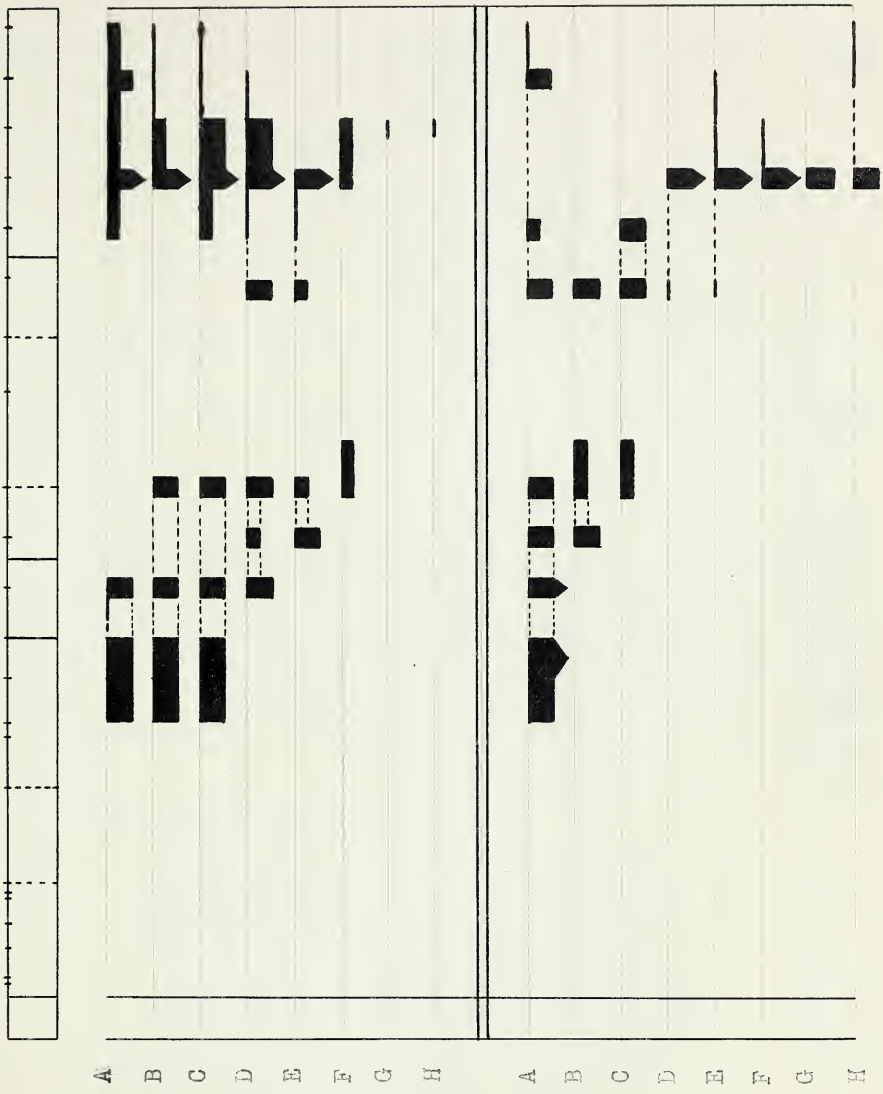

Figure XII

WELL-SECTION

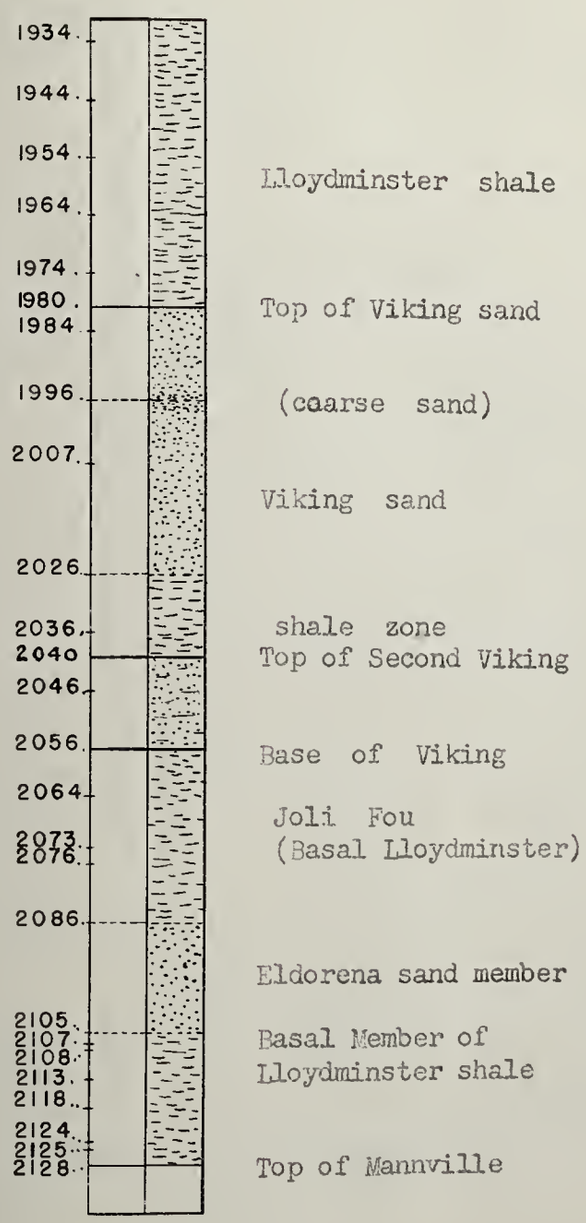

Figure XIII

CHAPTER III

Palaeo-ecological Significance of the Microfauna of the Basal Lloydminster Formation

The environments of deposition within the section can best be determined from a study of the ecology of the suites of fossils found at various horizons. These interpretations are based on an analysis of the specific fauna and the lithology of the stratigraphic horizon containing that fauna.

The presence of old soils and residual zones at the top of the Mannville formation, indicates the existence of a land area at the end of Mannville time. Within the time of deposition of the section being considered, this land mass was flooded by a sea that laid down the Basal Lloydminster shale. The earliest flooding is represented by shale which contains well-developed species of Gaudryina and Haplophragmoides, a few species of Ammobaulites and Glomospira, and a great number of Ammobaculoides. This assemblage indicates probable shallow water conditions, which is to be expected in the early stages of the advancement of the sea.

The fauna rapidly alters within a short vertical range, with the addition of several new, strongly developed species of Gaudryina, a few new species of Haplophragmoides and Ammobaculites, the complete disappearance of Ammobaculoides and the strong development of Proteonina. These changes are facies change due to a moderate deepening of the sea as it continued to flood over the land, although the appearance of Proteonina suggests brackish intervals.

Immediately below the Eldorena sand member the fauna changes considerably. All the species of Gaudryina dwindle to insignificance and subsequently disappear; all the species of Proteonina abruptly disappear; all species of Haplophragmoides show a marked decrease in numbers; and Ammobaculoides return very strongly. The subsequent deposition of the Eldorena sand indicates that at least locally the sea shallowed and is near shore at this horizon.

The Eldorena sand is glauconitic and therefore represents shallow marine deposition. The presence of a few poorly preserved Spores in the samples from immediately below and above this sand,

suggest near-shore phase of a deltaic environment.

The restricted vertical range of the genus Ammobaculoides to pre-Eldorena shales, indicates an early, local, shallow embayment into the late Mannville land area. It is known that the Eldorena sand facies is restricted in areal distribution.

When the source of the sand was cut off, probably by a deepening of the sea over the land area to the south, Joli Fou shales were laid down. These initial shales above the Eldorena sand member contain a different fauna to those shales immediately below the Eldorena sand member. The species of Haplophragmoides that were present below the sand are still present with the exception of 1 species, and 2 new species, including Haplophragmoides gigas appear. No species of Gaudryina or Ammobaculoides are present; only 1 species of Ammobaculites is present in these initial shales; and only 1 species of Proteonina is present. This indicates that the sea of post-Eldorena member time was fairly deep in this locality and too deep for the genus Ammobaculoides.

The index fossil Haplophragmoides gigas Cushman, has been reported from widespread localities throughout Alberta and Saskatchewan. It has been found in the Joli Fou shales of the Athabaska River (1), in Cretaceous sections of Southern Saskatchewan and Manitoba (2), in the Lloydminster shale at Lloydminster, Alberta (3), in Cretaceous shales of the section recovered from the Imperial Paddle River well (4) and in the Cretaceous shales of Southern Alberta near Taber (5). This indicates that the shore line of the H. gigas sea was at least 200 miles removed from the Eldorena location.

(1) Wickenden, R.T.D., 1949
"Some Cretaceous Sections along the Athabaska River etc." G.S.C. Preliminary Paper 49-15.

Bahan, W.G., 1950, Personal communication.

(2) Wickenden, R.T.D., 1945.
"Mesozoic Stratigraphy of the Eastern Plains, Manitoba and Saskatchewan". G.S.C. Memoir 239.

(3) Nauss, A.W., 1947.
"Cretaceous Micro-fossils of the Vermilion area, Alberta". Jour. Paleo. Vol. 21 #4.

(4) Stelck, C.R., 1950, Personal communication.

(5) Stelck, C.R., 1950, Personal communication.

The fauna of the shales imediately below the base of the Viking sand indicates a shallowing of the sea and in view of the subsequent deposition of the Viking sand, this is not unreasonable. This pre-Viking fauna contains 5 of the shallow water species of Haplophragmoides that appeared in the shales immediately above the Eldorena sand but not as strongly represented. The deeper water species Haplophragmoides gigas is gone. Four of the shallow water species of Ammobaculites that were present below the Eldorena sand member, reappear. Two new species of Proteonina are strongly developed here that, along with the genus Miliammina, first developed at this horizon with 3 very strong species, indicates brackish tendencies. The genus Hyperammina, initially develops here. This fauna represents a shallow, brackish water fauna and it is obvious that the deep sea aspect of the Haplophragmoides gigas Cushman is gone.

The shaly portions of the Second Viking sand contain the remnants of the pre-Viking fauna and a new fauna as well. One species of Haplophragmoides

is present that had pre-Viking affiliations and only one new species developed. Of the previous species of Ammobaculites there are three represented in the Second Viking sand and three new species developed. All pre-Viking sand species of Miliammina are present along with one new species. The one species of Hyperammina is still present. One new species of Verneuilina develops in the Second Viking sand (the 2 earlier species were restricted to the shales immediately below the Eldorena sand member). The two species of Proteonina that developed immediately below the base of the Viking, continue within the Second Viking and in addition, two new species are developed. There are four species of Reophax developed in this horizon only one of which is a continuation of an initial development in the shales immediately below the base of the Viking. "Spores" make their initial major appearance in this horizon. The evidence presented by an analysis of this fauna serves to indicate that the Second Viking sand represents a shallow near-shore facies of the earlier sea.

The shale zone immediately above the Second Viking sand carries a fauna which is very similar to the fauna of the Second Viking sand. The differences lie in the development of a few new species of Reophax, Proteonina, Miliammina, Hyperammina and Haplophragmoides replacing some of the species of the Viking sand. Little environmental change is indicated except the change from sand to shale bottom. The environment remained near-shore shown by the abundance of "Spores" present in this shale.

"Spores" dominate the organic life represented in the upper Viking sand. There are a few species of Ammobaculites represented near the top of the Viking sand, which had earlier affiliations within the section at the base of the Eldorena sand. Haplophragmoides is represented at the top of the Viking by two species, one of which was initiated in the shale zone above the Second Viking. Miliammina is represented by two species at the top of the Viking, which initiated within the Second Viking. There are five species of Hyperammina present at the top of the Viking, three of which were present earlier. Verneuilina is represented by the

one species that developed immediately below the base of the Viking. There are only two poorly represented species of Proteonina present at the top of the Viking, and one of these is a representation of a species which had its initial development immediately below the base of the Viking. Reophax and Gaudryina are represented by one poorly developed species each, the former being a continuation of a species initiated within the Second Viking and the latter a new species which is not represented above the Viking within the section studied. This indicates continuity of environment throughout the Viking sand with no major disruption in the index species of that environment of near-shore, slightly brackish, shallow water.

Summary:

The ecology of the faunas of the different horizons shows that the section essentially represents local fluctuations of a shallow, and at times, slightly brackish, transgressive sea in pre-Viking time and a static, shallow-water sea in post-Viking time. The continuity of the faunas through the Eldorena sand interval indicates that the latter represents local deposition in a local embayment. The widespread occurrence of the H. gigas fauna indicates that the deposition in this area during this time was deep water facies and over 200 miles from the shore in all directions.

The interval of the Viking sand probably represents a shallowing of the sea in the western part due to minor uplifts of the old source areas of the Blairmore-Kootenay series to the west. This uplift area also contributed detritus to the sands of the Viking. The presence of chert pebbles and chert grains in the Viking sand and the fact that there is no Viking sand developed in the Lloydminster area or in

Saskatchewan, tend to support this hypothesis. The fact that the Viking sand thickens to the west also affords credence to this tenet.

CHAPTER IV

CORRELATIONS

Microfaunal Correlations

The fauna of the Basal Lloydminster formation has been dated by C.R. Stelck (1) and J.H. Wall, Upper Albian age.

The writer finds that certain faunal assemblages contained within this section have been noted from other localities. Where possible, comparisons are made with these fossils and correlations indicated. That refinement of correlation may not be lost, the writer treats the correlations on the following stratigraphic breakdown.

(1) Stelck, C.R., 1950, Personal communication.

The suite of fossils from the pre-Eldorena member strata has been described from the Sikanni Chief River area (1) and from the Athabaska River area (2). The species listed by the writer as:

Haplophragmoides "E" found in Stelck's collection 299 feet below the top of the 1st Sikanni sandstone.

Haplophragmoides "B" found in Stelck's collection 167 feet below the Gastroplites zone in the upper Fort St. John shales.

Proteonina "C" found in Stelck's collection 148 feet below the top of the 1st Sikanni sandstone.

Ammobaculites "J" found in Stelck's collection 150 feet above the base of the Gastroplites zone. This fossil was also found in Bahan's collection 12 feet above the Grand Rapids sandstone in the Joli Fou shale.

(1) Stelck, C.R., 1950, "Cenomanian-Albian Foraminifera of Western Canada" unpublished Ph.D. thesis.
(2) Bahan, W.G., 1950, "Microfauna and Correlation of the Joli Fou formation" unpublished report.

Ammobaculoides sp. a few similar forms found in Bahan's collection 7 feet above the Grand Rapids sandstone in the Joli Fou shale.

This basal suite was not found by Nauss in the Lloydminster area. It is only partially represented in Bahan's collection from the Athabaska River. The suite is well represented in Stelck's collection from north eastern B.C. This indicates that the initial Basal Lloydminster sea was only present in the western portion of the basin and the stratigraphic position of this fauna seems to indicate uppermost Middle Albian or earliest Upper Albian age.

The post-Eldorena - pre-Viking shales contain the H. gigas fauna. Bahan and Wickenden (1) have reported this fauna in the Joli Fou shale. The writer has had access to and has examined carefully, the microfauna collected by Bahan from the Joli Fou

(1) Wickenden, R.T.D., 1949, "Some Cretaceous Sections along the Athabaska River, etc." G.S.C. Prelim. Paper 49-15.
Bahan, W.G., 1950, "Microfauna and Correlation of the Joli Fou formation" unpublished report.

shales of the Athabaska River and has found that those faunal assemblages that are developed throughout this section at the Eldorena location and those collected by Bahan are identical in nearly every respect. Some diagnostic fossils that were noted from both localities are the species listed by the writer as:

Glomospira "B" found in Bahan's collection 17 feet above the top of the Grand Rapids sandstone.

Haplophragmoides gigas found in Bahan's collection 17 feet above the top of the Grand Rapids sandstone.

Haplophragmoides "D" found in Bahan's collection 17 feet above the top of the Grand Rapids sandstone.

Ammobaculites "H" found in Bahan's collection 17 feet above the top of the Grand Rapids sandstone.

Haplophragmoides "I" found in Bahan's collection 22 feet above the top of the Grand Rapids sandstone.

Gaudryina canadensis found in Bahan's collection 22 feet above the top of the Grand Rapids sandstone.

Miliammina "C" was found in Bahan's collection 65 feet above the top of the Grand Rapids sandstone.

"Spores" the same forms were found in Bahan's collection 100 feet above the top of the Grand Rapids sandstone or 10 feet below the top of the Joli Fou shale.

In addition to those diagnostic species listed above numerous other minor forms not treated statistically by the writer, are found to be present in both the section below the Viking in the Eldorena well and below the Pelican sandstone in outcrop.

The presence of these nearly identical faunas in both sections allows a direct correlation of the two sections with the exception of the fauna of the initial shales of the Eldorena well section which is only partly represented in the initial Joli Fou shales.

The post-Viking shales within the section, contain a fauna that has been noted by the writer in

the collections of microfossils from the Upper Buckinghorse formation in the Sikanni Chief River area (1), the lower Shaftesbury formation on the Peace River near Peace River town (2), the Labiche shale immediately above the Pelican sand on the Athabaska River (3), and from the Lloydminster shale in wells near Lloydminster, Alberta (4). The following specific identities were established:

Trochammina sp. (a) found in Stelck's collections 284 feet below the top of the 1st Sikanni sandstone, in the upper Buckinghorse formation.

(1) Stelck, C.R., 1950, "Cenomanian-Albian Foraminifera of Western Canada" unpublished Ph.D. thesis.
(2) Nielsen, A.R., 1950, "A Microfaunal Study of the Shaftesbury formation" unpublished M.Sc. Thesis.
(3) Bahan, W.G., 1950, "Microfauna and Correlation of the Joli Fou formation" (unpublished).
(4) Nauss, A.W., 1947, "Cretaceous Microfossils of the Vermilion area, Alberta" Jour.Pal. Vol.21#4, pp.329-343.

(b) found in Nielsen's collection 274 feet below the Fish Scale sand in the lower Shaftesbury formation.

(c) found in Bahan's collection 17 feet above the top of the Pelican sandstone in the Labiche shale.

Verneuilina canadensis (a) found in Bahan's collection 30 feet above the Pelican sandstone in the Labiche shale.

(b) a form very similar found in Nielsen's collection 211 feet below the Fish-Scale sand in the lower Shaftesbury formation.

(c) a form very similar found in Stelck's collection 266 feet below the top of the 1st Sikanni sandstone in the upper Buckinghorse formation.

Verneuilina "D" (a) found in Stelck's collection 304 feet below the top of the 1st Sikanni sandstone in the upper Buckinghorse formation.

(b) found in Nielsen's collection 258 feet below the Fish-Scale sand in the lower Shaftesbury formation.

Reophax "J" (a) found in Stelck's collection 130 feet below the top of the First Sikanni sandstone in the upper Buckinghorse formation.

(b) found in Nielsen's collection 241 feet below the Fish-Scale sand in the lower Shaftesbury formation.

Hyperammina "E" (a) found in Nielsen's collection 280 feet below the Fish-Scale sand in the lower Shaftesbury formation.

(b) found in Bahan's collection 33 feet below the top of the Pelican sandstone.

Nodosinella sp. (a) found in Nielsen's collection 290 feet below the Fish-Scale sand in the lower Shaftesbury formation.

Tritaxia "A" (a) found in Nielsen's collection 274 feet below the Fish-Scale sand in the lower Shaftesbury formation.

There are several other species in Nielsen's collection that the writer found to be correlative with species in the Eldorena section but which for the sake of brevity have been omitted from this thesis.

Stratigraphic Conclusions

The faunas of the Eldorena section and those collected by Bahan from the Athabaska River are almost identical in all respects. This permits direct correlation between the Basal Lloydminster shales below the Viking sand and the Joli Fou shale; between the Viking sand and the Pelican sand; and between the Lloydminster shale immediately above the Viking sand and the lower Labiche shale immediately above the Pelican sand. The basal fauna below the Eldorena member was incompletely present in the Joli Fou shale on the Athabaska River suggesting that the earliest

Basal Lloydminster sea was only beginning to spread over the Athabaska River area at that time. Only a portion of this basal fauna of the Eldorena well-section is developed in the former area as the proper shaly environmental conditions were represented on the Lower Athabaska River by either sand facies of the uppermost Grand Rapids formation or actual sub-aerial conditions.

The Lloydminster shale at Lloydminster, Alberta and the Basal Lloydminster shales of the Eldorena well section are correlative except for the basal member and this correlation is substantiated by the microfauna developed therein. The faunas developed through the Viking interval in the Eldorena well-section are found to be laterally continuous into the Lloydminster area. The additional thickness of shale found in the Lloydminster area between the post-Viking - pre-Viking fauna indicates that the Lloydminster shale in the Lloydminster area has a shale facies representing the Viking sand interval of the Eldorena area without loss of stratigraphic section.

The pre-Eldorena member fauna is directly correlative with a fauna collected by Stelck from the upper Buckinghorse formation but the post-Eldorena member H. gigas fauna is missing from the upper Buckinghorse formation at that horizon. The post-Viking fauna of the Eldorena well-section however, is present in the upper Buckinghorse formation immediately superjacent to the pre-Eldorena faunal correlatives. This strongly suggests that there is a stratigraphic hiatus present in the upper part of the Buckinghorse formation in the Sikanni Chief River area of B.C.

The essential correlations developed or supported by this study are shown in the following table.

The faunal similarities outlined above indicate that the upper 200 feet of the Buckinghorse formation of north eastern B.C., the lower Shaftesbury formation (from 211 feet below the Fish-Scale sand to 290 feet below the Fish-Scale sand)

of the Peace River town area, and the lower Labiche shale immediately above the Pelican sand of the Athabaska River area, are correlative stratigraphically and ecologically similar to the Lloydminster shale immediately above the Viking sand in the Eldorena well-section.

SUMMARY TABLE

ELDORENA WELL	LOWER ATHABASKA R.	PEACE RIVER ALBERTA	SIKANNI CHIEF RIVER B.C.	LLOYDMINSTER ALBERTA
Late Post-Viking fauna		X sh Shaftesbury	X Sikanni ss	X sh Lloydminster
Post-Viking fauna	X Labiche sh	X sh Shaftesbury	X sh Buckinghorse	X sh Lloydminster
Upper Viking fauna	X Pelican ss			
Viking shale fauna				
Second Viking fauna	X Pelican ss			
Late Joli Fou fauna	X Joli Fou sh			X sh Lloydminster
H. gigas fauna	X Joli Fou sh			X sh Lloydminster
Pre- H. gigas fauna	X Joli Fou sh			X sh Lloydminster
Ammobaculoides fauna			X sh Buckinghorse	

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SAMPLE	CORRECTION FACTOR	MESH SIZE	HAPLOPHRAGMOIDES	AMMOBACULITES	AMMOBACULOIDES	REOPHAX	GAUDRYINA	VERNEUILINA	BATHYSIPHON	HYPERAMMINA	MILIAMMINA	GLOMOSPIRA	AMMODISCUS	TRITAXIA	PROTEONINA	EOGUTTULINA	GLOBIGERINA	COLLOPHANE SPHERES	TROCHAMMINA	LEPTODERMELLA	FUCOIDAL ELEMENTS	SPORES	NODOSINELLA
1934	x 1	48		1																			
	x 1	80		8					1	8	4												
	x 1	100	0	14		3			1	15	5	1							3	1			
	x12	150	0	5		6				18	20				1				8	5			
	Totals		0	83	0	75			2	239	249	1	0	0	12	0	0	0	99	61	0	0	
1944	x 1	48								2													
	x 1	80	3	20					0	42	18	2		1					3	2	0		
	x 1	100	10	87			1			18	28	1			1				16	1			
	x 3	150	11	19			4			38	20	2							12	1			
	Totals		46	164	0	0	13	0	0	176	116	9	0	1	1	0	0	0	55	6	0	0	
1954	x 1	48												1	1					1	4		
	x 2	80	3	26		5			6	11	8	1		3	2					3	52		3
	x 2	100	10	11		22	6	1	8	22	5	1	1		7				6	2	66		3
	x 5	150	10	4		12	7	2	20	17	11	3			2				0	2	60	1	
	Totals		76	94	0	114	47	12	128	151	81	19	2	7	29	0	0	0	12	21	540	5	12
1964	x 1	28				2																	
	x 1	48		5		19			2	7													
	x20	80	7	29		64	14	17	5	53	3				15				17	8			
	x20	100	30	7		16	7	18	1	39	15				11				27	1	4		
	x33	150	16	4		16	10	4		20	20				8				13	2	1		
	Totals		1268	857	0	2149	750	832	122	2507	1120	0	0	0	784	0	0	0	1309	246	113	0	
1974	x 1	48		4											1								
	x 1	80	6	29		1	1	2	3	1	5	1		1	2								
	x 1	100	4	13		3	10	1	2	3	4				5					4		5	
	x 2	150	1	2		3	11		4	3	6	1								2		2	
	Totals		12	50	0	10	33	3	13	10	21	3	0	1	8	0	0	0	0	8	0	9	
1984	x 1	48	6	4			2			3													
to	x 1	80	7	22		1		1		2					2							24	
1996	x 2	100	8	10			3	4		9					1			2				36	
	x 8	150	10	5			2	1		14	9	3			2			2			2	10	
	Totals		109	86	0	1	24	17	0	135	72	24	0	0	20	0	0	20	0	0	16	176	
2007	x 1	48																				23	
to	x 6	80	1								1							2				15	
2026	x 4	100				2	2								1			2		1		18	
	x 6	150				1	2		2								1	1		2		28	
	Totals		6	0	0	14	20	0	12	0	6	0	0	0	4	0	6	26		16	0	353	
2026	x5/3	48													1							63	
	x 4	80	22	16		3					3	4						18	2	1		27	
	x 4	100	32	22			5	5		1	6	2			8			2		4	2	17	
	x20	150	19	8		3	23	1		4	1	3			4			1		3	1	2	
	Totals		596	312	0	72	480	40	0	84	56	84	0	0	114	0	0	100	8	80	28	321	0
2036	x 1	28																				2	
	x 1	48	2			1									2							54	
	x5/3	80	12	8		6		1		8	4	1			5			4		1		38	8
	x 6	100	23	2		9	2	4		9	6	1			6			13		3		14	6
	x 6	150	26	4		5	4			10	1	2			2					1	1	16	1
	Totals		316	49	0	95	36	26	0	127	49	20	0	0	58	0	0	85	0	26	6	331	55
2046	x 1	28																				2	
	x 1	48	9	14		2									2							13	
	x20	80	26	49		16	3	3			3				8				2			4	
	x12	100	40	30		20	1	21		4	2				13				1	1		2	
	x 6	150	16	10		5	10	10		3	10				1	1		3				5	
	Totals		905	1414	0	592	132	372	0	64	144	0	0	0	324	6	0	18	52	12	0	149	0
2056	x 1	28																					
to	x 1	48	12	11					6						1								
2064	x10	80	65	68		1			1						1								
	x 6	100	110	59		5		3			12				4				1				
	x12	150	90	15		4	7	2		9	7				2				2				
	Totals		2162	1225	0	88	74	42	16	96	156	0	0	0	59	0	0	0	30	0	0	0	0
2064	x 1	48	12	6										1					1				
to	x 4	80	71	33						4	2	1							1	1			
2073	x 4	100	58	16			1			10	14	2											
	x5/2	150	70				9		1	7	22	3						1					
	Totals		703	202	0	0	27	0	2	74	119	20	0	0	0	0	0	2	5	4	0	0	0
2076	x 1	48	3	1											1								
to	x 6	80	92	4			15			2	1	2			2			1			2		
2086	x 6	100	110	17			17	1		8		5			3			1			2		
	x10	150	56	6			11	4		2	3							1					
	Totals		1775	187	0	0	302	46	0	80	36	42	0	0	31	0	0	22	0	0	24	0	0
2105	x 1	28	1																				
	x 1	48	7	12					1													2	
2107	x 5	80	32	25	25		12														1	6	
	x 5	100	44	32	28		40	3		1					2						1		
	x10	150	51	29	24	2	10	9		4					1			1					
	Totals		898	587	505	20	36	105	1	45	0	0	0	0	20	0	0	10	0	0	10	32	0
2108	x 1	28	1																				
	x5/2	48	15	20	5	2						2			17							4	
2113	x20	80	30	21	3		22			2		1			28					1		4	
	x 5	100	28	25	33		26	1		4					7					1		1	
	x20	150	35	12	6		11	3							3								
	Totals		1479	1875	358	5	790	65	0	60	0	25	0	0	698	0	0	0	0	25	0	95	0
2113	x 1	28	1																				
	x 1	48	28	25			2			2					8								
2118	x10	80	35	13	2	5	9	2		5					57							1	
	x 5	100	44	15	11	1	22					3			48					1			
	x10	150	17	3	4		18			3		6			4								
	Totals		769	260	115	55	382	20	0	82	0	75	0	0	858	0	0	0	0	5	0	10	0
2118	x 1	28	1																				
	x 1	48	14	18			1								13								
2124	x 5	80	29	46			23			2					44							1	
	x5/2	100	55	27			36					1			25								
	x10	150	42	10			42	2		2		9			6								
	Totals		718	416	0	0	626	20	0	30	0	93	0	0	356	0	0	0	0	0	0	3	0
2125	x 1	28																					
	x 1	48	4	6	2							1			2							5	
2128	x 5	80	24	9	59*		20	1	1	2		2						1				4	
	x 5	100	41	22	90		34			3		2										3	
	x33	150	21	11	47		22			2												1	
	Totals		1022	524	2298	0	996	5	5	91	0	21	0	0	2	0	0	1	0	0	0	73	0

* 2 Spiroplectammina

STATISTICAL SPECIFIC RECORD
OF THE GENUS
HAPLOPHRAGMOIDES

Sample	Mesh Size	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Gigas
1964	80														1				
	Totals														20				
1974	80														3				
	Totals														3				
1984	48																6		
to	80															2	1		
1996	Totals															2	7		
2026	80				3										11	3			
	Totals				12										44	12			
2036	48				1														
	80														8				
	Totals				1										13				
2046	48			1											9				
	80			3											12				
	Totals			61											249				
2056	48				5			1		1			1						
to	80		1	2						2		14	3	3					
2064	Totals		10	20	5			1		21		140	31	30					
2064	48				10														
to	80			2			12		2	2		2	5						1
2073	Totals			8	10		48		8	8		8	20						4
2076	48																		
to	80	5	3	17	21		7		1	3	9								3
2086	Totals	30	18	102	126		42		6	18	54								18

STATISTICAL SPECIFIC RECORD
OF THE GENUS
HAPLOPHRAGMOIDES
Continued

Sample	Mesh Size	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Gigas
2105	28	1																	
to	48	5			2														
2107	80			2	7		2	1		1									
	Totals	6		10	37		10	5		5									
2108	28	1																	
to	48	2	1				1	1											
2113	80	4		6	2	2	1	4	1										
	Totals	86	3	120	40	40	23	83	20										
2113	28	1																	
to	48	4	3		5	5													
2118	80			3	3	1	5												
	Totals	5	3	30	35	15	50												
2118	28	1																	
to	48	5	1		4														
2124	80	2	3	6	9														
	Totals	16	16	30	49														
2125	48	3	1																
to	80	2	2	2															
2128	Totals	13	11	10															

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STATISTICAL SPECIFIC RECORD
OF THE GENUS
AMMOBACULITES

Sample	Mesh Size	A	E	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1934	80					1													5
	Totals					1													5
1944	80			1		2												1	14
	Totals			1		2												1	14
1954	80			4		10			1								5	2	
	Totals			8		20			2								10	4	
1964	48			1		3											1		
	80			17	1	13			3								4	1	
	Totals			341	20	263			60								81	20	
1974	48					2										1			
	80			13		12											3		
	Totals			13		14										1	3		
1984	48					2										1			
to	80			10		7									1	4			
1996	Totals			10		9									1	5			
2026	80					11								4					
	Totals					44								16					
2036	80					5									1				
	Totals					8									2				
2046	48					7								3					
	80				1	38			3				1	11	6				
	Totals				20	760			60				20	223	120				
2056	48					2		1	1			2							
to	80				14	18			7				30						
2064	Totals				140	182		1	71			2	300						

STATISTICAL SPECIFIC RECORD
OF THE GENUS
AMMOBACULITES
Continued

Sample	Mesh Size	A	E	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
2064	48				2	3													
to	80				17	9													
2073	Totals				70	39													
2076	80				1														
to	Totals				6														
2086																			
2105	48			5	1	1			4										
to	80			2	5	18	2		4		2								
2107	Totals			15	26	91	10		24		10								
2108	48	6		8	1	6		2	2										
to	80			7	27	16	4	2	4	1									
2113	Totals	15		160	543	335	80	45	85	20									
2113	48	2		10	2	2													
to	80			1	11														
2118	Totals	2		20	112	2													
2118	48	1		17															
to	80			5	15														
2124	Totals	1		42	75														
2125	48	3																	
to	80	5	3																
2128	Totals	28	15																

STATISTICAL SPECIFIC RECORD
OF THE GENUS
PROTEONINA

Sample	Mesh Size	A	B	C	D	E	F	G	H	I	J	K	L	M
1954	80					1								
	Totals					2								
1964	80			1	1									
	Totals			20	20									
1974	80									1				1
	100							1		2				
	150								1		2			
	Totals							1	2	3	4			1
1984 to 1996	80								1				1	
	Totals								1				1	
2026	48											1		
	80								3					
	Totals								12			2		
2036	80							1	3	1	1			
	100							2	1	2	3			
	Totals							14	11	14	20			
2046	48							1	1					
	80							7	13	3	1			
	Totals							36	66	15	5			
2056 to 2064	100							6	4					
	Totals							36	24					
2076 to 2086	80			1										
	Totals			6										

STATISTICAL SPECIFIC RECORD
OF THE GENUS
PROTEONINA
Continued

Sample	Mesh Size	A	B	C	D	E	F	G	H	I	J	K	L	M
2108	48	2		2	9	2								
to	80	4	2	14	3	1	2							
2113	Totals	85	40	285	83	25	40							
2113	48	3	1	1	2									
to	80	21	2	21	6									
2118	Totals	213	21	211	62									
2118	48	7	1											
to	80	24	9	9										
2124	100	7	3	3	3									
	Totals	145	54	53	8									

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STATISTICAL SPECIFIC RECORD
OF THE GENUS

		MILIAMMINA								HYPERAMMINA							
Sample	Mesh Size	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
1934	80	5								5							1
	100	4	2	4													
Totals		9	2	4						5							1
1944	48	1															
	80	27								33				1	5		2
	100	22	4	4	3												
Totals		50	4	4	3					33				1	5		2
1954	80	4		4				1						1			
	100			4			1		2								
	150		2	4	5		1										
Totals		8	10	36	25		7	2	4					2			
1964	80	2					1						7	30	16	2	3
	100	5		3	3	1											
	150	1	5	4	4	3											
Totals		173	165	192	192	119	20						140	600	320	40	60
1974	80	5		2						2							
	100	4		2						2		12					
	150			3	1	2				3		11					
Totals		9		10	2	4				10		34					
1984	48												2	1			
	80												2				
	100				2					1	7						
	150				4	2				3	5	5					
Totals					36	16				26	54	40	4	1			
2007	80						1										
to	100										2	1					
2026	150											1					
Totals							6				8	10					

| | | |

Continued

Sample	Mesh Size	MILIAMMINA A	B	C	D	E	F	G	H	HYPERAMMINA A	B	C	D	E	F	G	H
2026	80					3				2							
	100		1	4	1					3							
	150		1	2	1					1	1	1					
Totals			24	56	24	12				40	20	20					
2036	80									10	4						
	100				1	5				3	7						
	150					1				7	5						
Totals					6	36				77	79						
2046	80	1		3													
	100	1			1					7							
	150		8		2					4							
Totals		32	48	60	24					108							
2056 to 2064	100	5	2	4						3							
	150	2	2	3						12							
Totals		54	36	60						162							
2064 to 2073	80	2								4							
	100	4	5	4						7							
	150	15	4	4						11							
Totals		62	30	26						72							

STATISTICAL SPECIFIC RECORD
OF THE GENUS

VERNEUILINA

Sample	Mesh Size	A	B	C	D	Canadensis
1944	48					
	80					
	Totals					
1954	80		1			
	100					
	150					
	Totals		2			
1964	80	5	3	3	6	1
	100					
	150					
	Totals	100	60	60	120	20
1974	80			2	1	
	Totals			2	1	
1984 to 1996	80			1		
	Totals			1		
2026	80					
	100					
	150					
	Totals					
2036	80					
	150					
	Totals					
2046	80			5		
	Totals			100		

GLOMOSPIRA

Sample	Mesh Size	A	B	C	D	E	F	G	H	I
1944	48									1
	80					2				2
	Totals					2				3
1954	80									
	100					1				
	150								1	
	Totals					2			5	
1964	80									
	100					2		2		
	150					1				
	Totals					73		40		
1974	80									
	Totals									
1984 to 1996	80									
	Totals									
2026	80							1	1	
	100	1						1		
	150							3		
	Totals	4						68	4	
2036	80						3			
	150		1							
	Totals		6				5			
2046	80									
	Totals									

Continued

Sample	Mesh Size	VERNEUILINA A	B	C	D	Canadensis	GLOMOSPIRA A	B	C	D	E	F	G	H	I
2064	80										1				
to	100										3				
2073	150										2				
Totals											21				
2076	80									1					
to	100									1	2				
2086	Totals									12	12				
2105	80	1	1												
to															
2107	Totals	5	5												
2108	48						1								
to	80	1							1						
2113	Totals	20					2		20						
2113	80	3	4												
to	100						2								
2118	150							6							
Totals		30	40				10	60							
2118	100							1							
to	150							9							
2124	Totals							93							
2125	48						1								
to	80						2								
2128	100						1								
Totals							16								

| | | |

STATISTICAL SPECIFIC RECORD
OF THE GENUS
GAUDRYINA

Sample	Mesh Size	A	B	C	D	E	F	G	H	I	J	K	L	Canadensis	cf Canadensis
1954	80			1											
	Totals			2											
1964	80			2	2	1	1					1	2		
	Totals			40	40	20	20					20	40		
1974	80				1										
	Totals				1										
1984	48											1			
to	80														
1996	Totals											1			
2076	80			3	2					6					
to	Totals			18	12					36					
2086															
2105 to	80				1	1	1	1	2	1	3			1	
2107	Totals				5	5	5	5	10	5	15			5	
2108	80			7	1	3		1	2					1	1
2113	Totals			140	20	60		20	40					20	20
2113	48						1								1
to	80			2			1	1							
2118	Totals			20			11	10							10
2118	48						1								
to	80			6	2	5	2	3						2	1
2124	Totals			30	10	25	11	15						10	5
2125	80	2	1	4	2	1								4	1
2128		10	5	20	10	5								20	5

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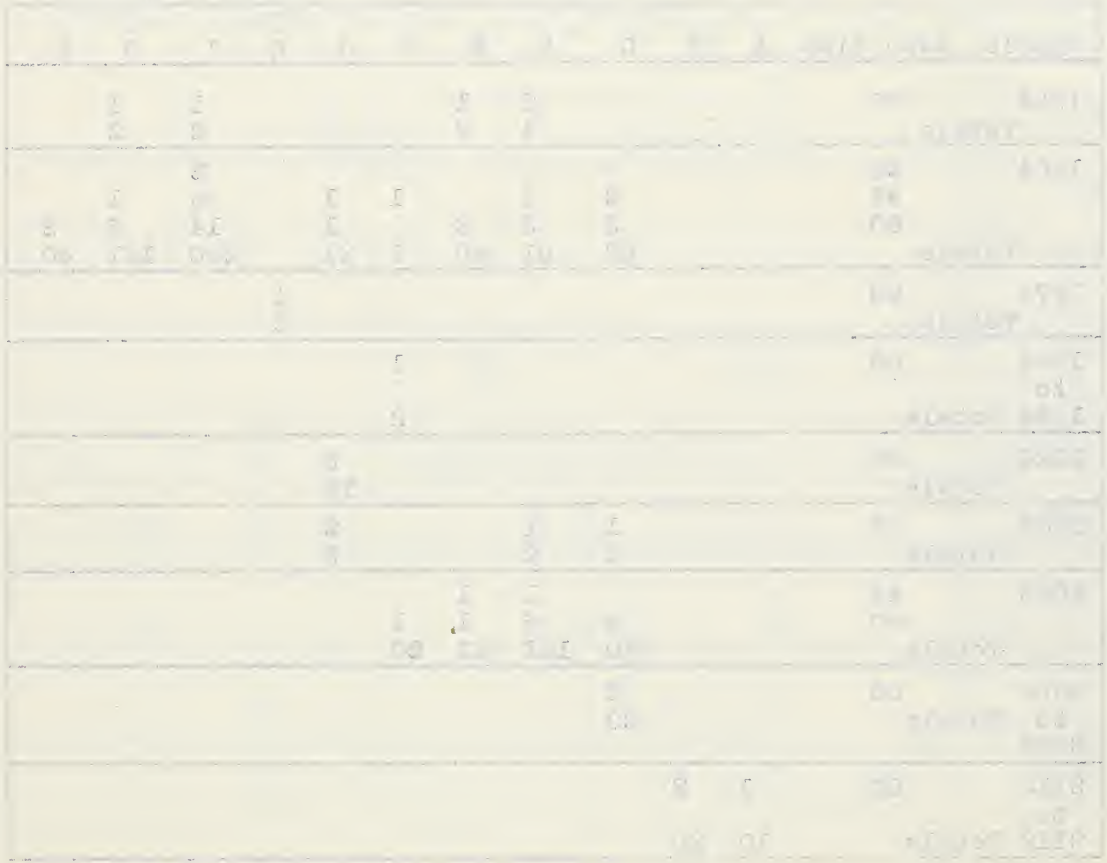
STATISTICAL SPECIFIC RECORD
OF THE GENUS
REOPHAX

Sample	Mesh Size	A	B	C	D	E	F	G	H	I	J	K
1954	80				2	1				1	1	
Totals					4	2				2	2	
1964	28									2		
	48			2	1		1	1		8	1	
	80			3	3	2		1		14	6	2
Totals				62	61	40	1	21		290	121	40
1974	80								1			
Totals									2			
1984 to 1996	80						1					
Totals							2					
2026	80							3				
Totals								12				
2036	80			1	1			2				
Totals				2	2			3				
2046	48				1	1						
	80			4	6	1	1					
Totals				80	121	21	20					
2056 to 2064	80			2								
Totals				20								
2113 to 2118	80	1	2									
Totals		10	20									



PERCENTAGE POPULATION TABLE

Sample	Haplophragmoides	Ammobaculites	Ammobaculoides	Reophax	Hyperammina	Proteonina	Leptodermella	Gaudryina	Verneuilina	Trochammina	Miliammina	Spores	Others	Total %
1934	0	10	0	9	29	2	8	0	0	12	30	0	0	100
1944	8	28	0	0	30	0	1	2	0	9	20	0	2	100
1954	6	7	0	8	11	2	41	4	1	2	6	0	12	100
1964	10	8	0	17	20	5	2	7	8	10	9	0	4	100
1974	7	29	0	6	6	4	4	19	1	0	11	5	8	100
1984-1996	15	12	0	0	19	3	0	3	2	0	10	25	11	100
2007-2026	1	0	0	3	0	1	3	5	0	0	1	76	10	100
2026	24	13	0	3	4	5	3	20	2	0	2	13	11	100
2036	24	4	0	7	10	4	2	3	2	0	4	26	14	100
2046	21	34	0	14	1	8	0	3	9	1	3	3	3	100
2056-2064	54	30	0	2	2	1	0	2	1	1	4	0	3	100
2064-2073	58	17	0	0	6	0	0	2	0	0	10	0	7	100
2076-2086	71	7	0	0	3	1	0	12	2	0	1	0	3	100
2105-2107	39	25	22	1	2	1	0	2	5	0	0	1	2	100
2108-2113	27	34	6	0	1	13	0	14	1	0	0	2	2	100
2113-2118	29	10	4	2	3	33	0	15	1	0	0	0	3	100
2118-2124	31	18	0	0	1	15	0	27	1	0	0	0	7	100
2125-2128	20	10	46	0	1	0	0	20	0	0	0	1	2	100

Date	Water temp.	Oxygen	Specific conductance	Alkalinity	Bicarbonate	Chloride	Hardness	Calcium	Magnesium	Sodium	Potassium	Sulfate	Fluoride	Silica	Iron	Manganese	Boron	Phosphate	Nitrate	Ammonia	Organic nitrogen	Total solids	Suspended solids	Dissolved solids	Turbidity	Color	Coliform bacteria	Fecal coliform bacteria	Fecal streptococcus bacteria
10/1/68	12.0	10.2	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/2/68	12.0	10.1	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/3/68	12.0	10.0	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/4/68	12.0	9.9	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/5/68	12.0	9.8	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/6/68	12.0	9.7	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/7/68	12.0	9.6	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/8/68	12.0	9.5	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/9/68	12.0	9.4	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/10/68	12.0	9.3	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/11/68	12.0	9.2	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/12/68	12.0	9.1	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/13/68	12.0	9.0	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/14/68	12.0	8.9	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/15/68	12.0	8.8	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/16/68	12.0	8.7	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/17/68	12.0	8.6	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/18/68	12.0	8.5	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/19/68	12.0	8.4	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/20/68	12.0	8.3	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/21/68	12.0	8.2	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/22/68	12.0	8.1	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/23/68	12.0	8.0	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/24/68	12.0	7.9	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/25/68	12.0	7.8	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/26/68	12.0	7.7	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/27/68	12.0	7.6	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/28/68	12.0	7.5	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/29/68	12.0	7.4	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/30/68	12.0	7.3	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500
10/31/68	12.0	7.2	1,200	320	390	120	440	110	42	110	3.0	180	0.2	12	0.10	0.02	0.1	0.02	0.2	0.02	0.4	720	10	710	2	5	2,400	1,100	1,500